

AGE DIFFERENCES IN ROAD CROSSING DECISIONS BASED ON GAP JUDGEMENTS

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ABSTRACT

Older pedestrians are over-involved in serious injury and fatal crashes compared to younger adults. This may be due, in part, to diminished perceptual, cognitive and motor skills which act to reduce the older person's ability to sense danger and take measures to avoid hazards. Two experiments are described in this paper which examine age differences in gap selection decisions in a simulated road crossing environment. The results demonstrated age differences in the decision-making process, particularly a difficulty in estimating appropriate time-of-arrival of oncoming traffic along with an inability to allow for slower decision times and walking speeds. A two-phase model of road crossing decisions is discussed within a limited information processing approach and it is suggested that older adults experience problems in quickly and instantaneously calculating distance and velocity information in order to select safe margins in which to cross the road.

MAKING THE DECISION about when it is safe to cross roads in relation to available traffic gaps is a difficult everyday task and may be especially difficult for older pedestrians. Given the literature demonstrating age-related changes in performance [Corso, 1981; Salthouse, 1991; Korteling, 1994], it is conceivable that the road crossing behaviour of older adults may explain, in part, the increased rate of pedestrian injury crashes for this age group compared with younger adults. A series of observational studies [Oxley, Fildes, Ihsen, Charlton & Day, 1997a] identified a number of dangerous practices that some older adults adopt when crossing the road. The findings of this study suggested that some older pedestrian crashes may be related to difficulties in accurately or appropriately judging safe gaps in the traffic in which to cross.

Accurate perception of the motion of approaching vehicles is paramount when making judgements of the traffic in which to cross safely. However, the ability to estimate the time-of-arrival of the closest vehicle in order to make a safe decision may be difficult for older adults, especially in conditions of uncertainty or when a decision needs to be made quickly. This difficulty has been emphasised by others who argue that age differences in motion perception in critical traffic situations is an important factor in older road users' over-involvement in crashes [Cavallo & Laurent, 1988; Staplin & Lyles, 1991; Carthy, Packham, Salter & Silcock, 1995]. The evidence regarding age-related deficits in motion detection suggests that older adults experience difficulty perceiving the details of moving objects [Burg, 1966; Kosnik, Winslow, Kline, Rasinski & Sekuler, 1988], tracking fast moving stimuli [Sharpe & Sylvester, 1978] and are less accurate in estimation of time-of-arrival than younger adults [Schiff, Oldak & Shah, 1992]. The processes involved in making these estimates, however, is less clear. For instance, the ecological or direct perspective suggests that, under conditions of constant approach velocity, time-to-contact can be specified directly from a single parameter available within the optic flow field [Lee, 1974; Tresilian, 1991]. In contrast, the computational or indirect perspective would suggest that information for time-of-arrival is generated by instantaneous computation of the ratio between observer-object distance and the instantaneous relative velocity of the object or surface - this is termed the distance/velocity model [Cavallo & Laurent, 1988; Scialfa, Guzy, Leibowitz, Garvey & Tyrell, 1991]. Even less clear is the capacity of older adults to optimise their use of available sources of perceptual information for judging impending collisions with traffic.

As a consequence, it may be that older adults experience difficulty in selecting appropriate gaps in the traffic to compensate

for their slower walking speeds. Lee, Young and McLaughlin (1984) claimed that perceiving the affordance of a gap entails combining information about the environment with information about one's own walking pace, however, older adults may be less able than their younger counterparts to compensate adequately for age-related declines. Others, too, have argued that some older people may not be aware of the impact of ageing on the ability to perform tasks and the extent of these declines [Sabey, 1988; Holland & Rabbitt, 1992] and thus may behave in a risky fashion while crossing the road. In addition, Yanik and Monforton (1991) suggested that age-related losses may accumulate in the oldest old to a point where they overwhelm some of the normal attempts at compensation. While there is wide variability among older adults, impairments do not occur all at once, nor do they occur at the same rate in different individuals, an investigation of the ability to make gap selection decisions is critical to understand the difficulties some older pedestrians may experience in crossing roads.

This paper presents the results of two experimental studies which were conducted in order to investigate in detail the decision making processes involved in deciding whether to cross a road or not in a simulated road crossing task. Experimental studies have long been recognised as an important method in examining human performance and provide a good method to examine in detail the various factors likely to influence road crossing performance.

EXPERIMENT ONE

The first study aimed to investigate age effects on decisions concerning the safety of crossing based on estimation of the time-of-arrival of oncoming vehicles and the perception of safe margins.

METHOD

Participants - Fifty four participants took part in this experimental study. Three groups consisted of 18 young adults aged between 30 and 45 years, 18 young-old adults aged between 60 and 69 years and 18 old-old adults aged 75 years and over. All participants were volunteers and in good health. All participants completed a battery of functional assessments. This revealed group differences with the oldest group performing more poorly than younger adults on cognitive, perceptual, visual and physical measures but within the normal range.

The Simulated Road Environment – A validation study was initially conducted to test the ability of an experimental setup to

simulate real world conditions. This study showed a high correlation of yes/no crossing decisions and moderate correlation of safety ratings between real world conditions and when viewing images of these environments by both younger and older pedestrians [Oxley et al., 1997b]. A simulated road environment was therefore utilised in these experiments. Moving traffic scenes were generated from data files from a mid-level driving simulator. Data files were downloaded onto VCR tapes and then projected onto a large curved white screen.

The road environment depicted an undivided two-way residential road from the perspective of a pedestrian waiting at the kerb in which two near-side approaching vehicles were depicted (that is, vehicles travelling from the right from the perspective of the pedestrian in Australia*). In addition, the approach of the vehicles was audible. No far-side approaching traffic was included. Time-of-arrival and vehicle speed of the vehicles were manipulated with five levels of time-of-arrival (1, 4, 7, 10 and 13 seconds) and three levels of vehicle speed (40, 60 and 80km/h). The levels and time-of-arrival were chosen as theoretical safe and unsafe times, based on group average walking speeds identified in previous observational studies [Oxley et al., 1997a]. Fifteen traffic scenes were downloaded onto three separate video tapes in random order and each participant viewed each of the three video tapes in which the presentation was counterbalanced. In total, each participant viewed the fifteen scenes three times, that is, a total of 45 traffic scenes.

Participants were seated at a desk in a darkened quiet room in front of the screen. They were instructed to respond to each traffic scene as if they were to cross the road immediately behind the first vehicle and in front of the second vehicle. On the desk in front of them was a keyboard with most of the keys blackened and covered on which they were asked to make their responses. Keys labelled 'YES' and 'NO' were available for participants to respond if they would cross the road or not. In addition, numbers 1 to 9 with labels at each end ('very unsafe' below the 1 key and 'very safe' below the 9 key) provided a nominal rating scale on which participants were asked to rate the safety of the road crossing (Fig. 1).

Participants were given practice trials until they fully understood the task. On all trials they were instructed to place their right and left index fingers on the YES and NO keys until they heard a buzzer. The buzzer sounded as the first trigger vehicle passed the point of crossing and at the same time activated a timer. Once participants heard this they were instructed to look at the traffic

* Vehicles in Australia drive on the left-hand side of the road, and contrary to those in USA and most European countries.

scenes and decide whether or not they would cross and make their response as soon as possible. After this response they were asked to rate how safe or unsafe they thought the crossing would have been.



Figure 1: Experimental setup

RESULTS – Three measures of performance were analysed including yes/no responses, decision time and safety rating responses.

Yes/no responses – These responses indicated whether individuals would have crossed the road or not, based on the approaching vehicle. While a yes or no response in itself is an interesting measure, it seemed important to take walking speed into account when examining crossing decisions.

Group differences were found for walking speeds both at fast and normal walking paces. When walking at a normal pace the youngest group walked faster than the young-old group ($t_{(34)}=4.55$, $p<0.001$), who walked faster than the old-old group ($t_{(34)}=5.96$, $p<0.001$). Similarly, at a fast walking pace the youngest group walked faster than the young-old group ($t_{(34)}=5.39$, $p<0.001$), who walked faster than the old-old group ($t_{(34)}=5.09$, $p<0.001$).

Analysis of crossing responses therefore, was undertaken by employing hierarchical logistic regression modelling of the data to examine the independent variables including age, time-of-arrival, vehicle speed and gap distance while holding the effects of mobility statistically constant. All variables were found to be significant predictors of crossing decisions (Table 1).

Table 1: Predictors of crossing decisions

| <u>Predictor</u> | <u>χ^2 value</u> |
|------------------|----------------------------------|
| Walking Speed | 32.21** |
| Age Group | 153.5** |
| Time-of-arrival | 441.68** |
| Vehicle Speed | 90.00** |
| Gap Size | 436.27** |

(**p<0.001)

Time-of-arrival was the greatest predictor of crossing decisions and the proportion of yes responses by time-of-arrival and age group is shown in Figure 2. Regardless of mobility effects, the youngest group was more likely to indicate they would have crossed across all time-of-arrival conditions than the older groups. While the old-old group were least likely to indicate they would have crossed than any other group in most time-of-arrival conditions, an exception was in the 4 second time-of-arrival condition, in which a greater proportion of the old-old group responded yes than the young-old group (22% versus 17% respectively).

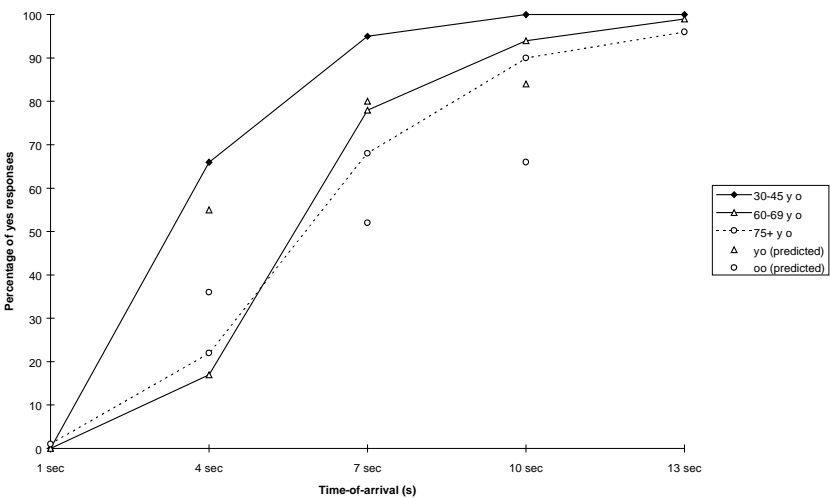


Figure 2: Proportion of yes responses - time-of-arrival by age group (predicted values represented proportion of the walking speed of the young group)

The expected proportion of yes responses for the young-old and the old-old group expressed as a proportion of the walking speed of the young group is also shown in Figure 1. In the 4 second time-of-arrival condition both of the older groups made fewer yes responses than predicted, particularly the young-old group. Predicted measures expected this group, on average, to indicate they

would have crossed 55% of the time, however, only 17% responded yes. Further, predicted measures expected the old-old group, on average, to indicate they would have crossed 36% of the time, however, only 22% responded yes. This suggests conservative crossing decisions, particularly for the young-old group in this condition. In contrast, for the 7 and 10 second time-of-arrival conditions, the young-old group responded similarly to that expected, whereas a greater proportion of the oldest group responded yes than predicted (68% versus 52% in the 7 second condition and 87% versus 62% in the 10 second condition). These findings suggest that the oldest group made a greater proportion of potentially less safe decisions than their younger counterparts based on their average walking speed.

Decision time was measured as the time the trigger vehicle passed to the time that a yes/no response was made and was analysed by employing two-way repeated measures ANOVA. Mean decision time by age group is shown in Figure 2. As age increased, so did decision time for all traffic conditions ($(f_{(51,2)}=40.34, p<0.001)$). The oldest group took significantly longer than the younger groups to make their decision concerning whether they would cross the road or not. On average, the young group took just over 600ms to respond, while the oldest group took over twice as long (1400ms). Further, the oldest group was more variable than the young-old group, who were more variable than the youngest group.

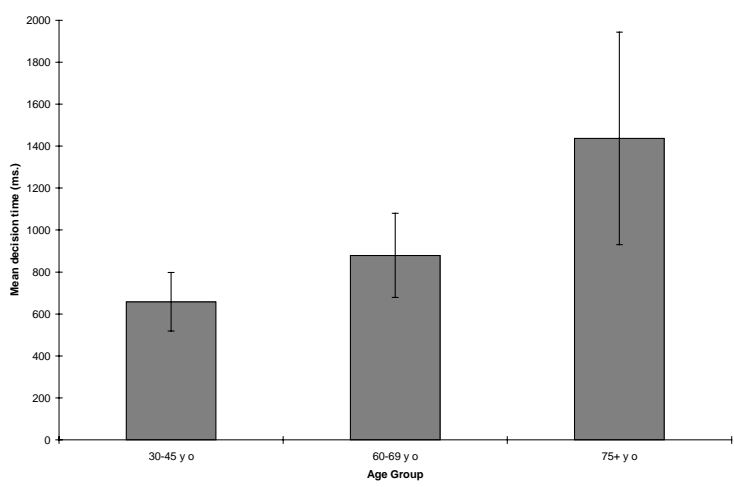


Figure 2: Mean decision time by age group

Decision time, walking time and time-of-arrival were combined to arrive at an estimate of safety margins. Safety margin was calculated as the mean individual walking time of normal and fast walking pace plus decision time on each trial subtracted from the time-of-arrival in each traffic condition. Distributions of crossing

time by safety margins revealed group differences. The distribution of safety margins for each group for the most critical time-of-arrival conditions (4 and 7 seconds) are shown in Figure 3.

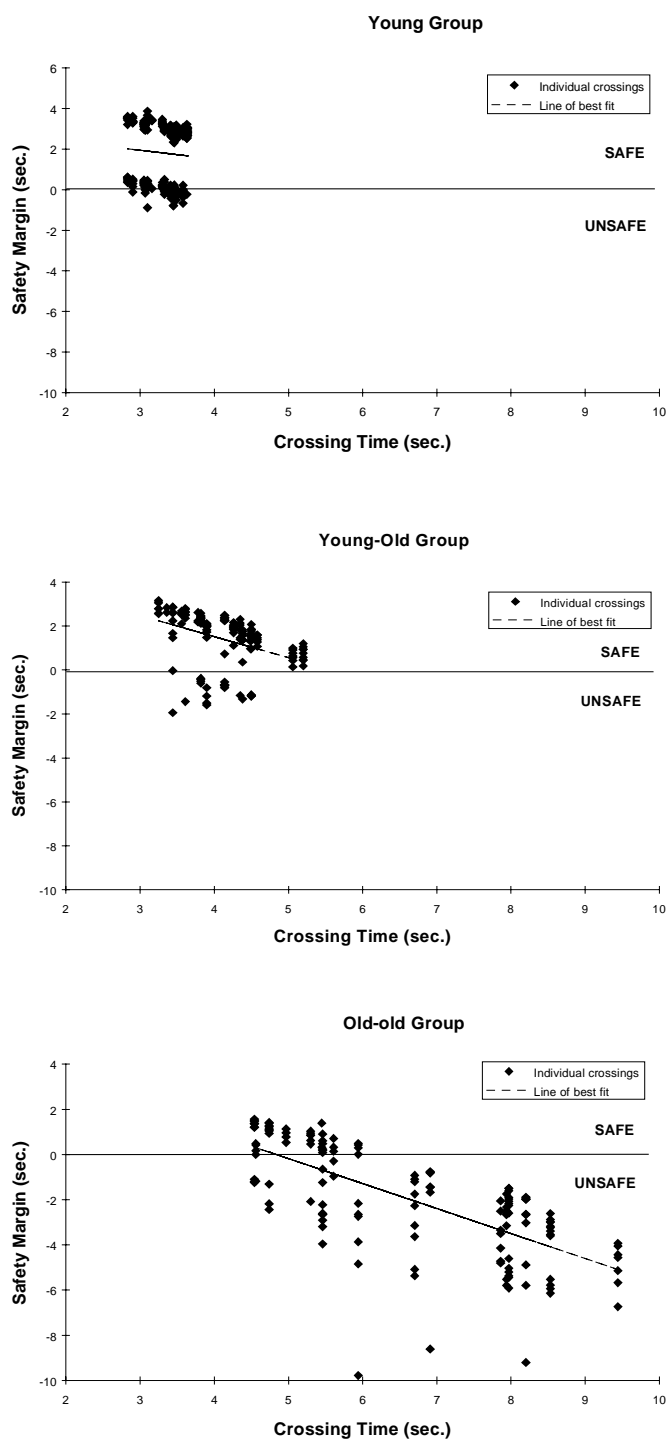


Figure 3: Safety margin distributions of each group for critical time-of-arrival conditions (4 and 7 seconds)

The line intersecting the zero safety margin denotes where time-of-arrival and crossing time coincide. Any point below this line indicated an unsafe crossing, while points above the line indicate a safe crossing. The distributions show that for all age groups level of safety margin accepted decreased as crossing time increased and this was particularly so for the oldest group.

Group differences are also apparent. The distribution of the young participants shows little variability and fast crossing times, along with only a small proportion indicating they would have crossed in an unsafe manner. Moreover, the unsafe crossings for this group were only marginally unsafe, generally falling between the zero line and -1 second. In contrast, the distributions of the older groups showed more variability, slower crossing times and a tendency for the slower walkers to cross in a more unsafe manner than the fast walkers. This was most noticeable in the old-old group. A larger proportion of participants in this group, compared with the younger groups, indicated they would have crossed with unsafe margins than in other groups. In addition, the margins extended from the zero line to -10 seconds. It appears that the oldest and slowest participants made the most potentially unsafe crossing decisions in these critical time-of-arrival conditions.

Safety Rating Responses - The safety rating responses were analysed using a three-way repeated measures ANOVA and panel regression modelling to reveal the unique contribution of each variable to rating responses irrespective of mobility differences. The findings for the rating responses were comparable with the yes/no responses, where all independent variables (age, time-of-arrival, vehicle speed and gap distance) predicted safety rating responses. Time-of-arrival and gap distance were strong predictors of rating responses, while vehicle speed contributed less than the other variables.

Figure 4 shows the mean safety rating responses by time-of-arrival and age group. Significant main effects for group ($f_{(204,8)}=6.14$, $p<0.001$) and for time-of-arrival ($f_{(204,4)}=13.04$, $p<0.001$) were found. Further, an interaction of group by time-of-arrival was revealed ($f_{(204,8)}=6.14$, $p<0.001$). The youngest group consistently made higher rating responses than the older groups across all time-of-arrival conditions, even with the effects of walking speed controlled for. This suggests that perceived risk by the youngest group was lower than that of the older groups.

Further, predicted responses based on average walking speeds are also shown in Figure 4. The young-old group responded similarly to that predicted in the 7 and 10 second time-of-arrival conditions. Only in the 4 second time-of-arrival condition their responses were different than predicted. In this condition, their perceived risk was higher than expected, suggesting adoption of a more conservative strategy. In contrast, the rating responses of the old-old group were higher than expected in all critical time-of-arrival conditions. In other words, their perceived risk was lower than expected - a risky strategy.

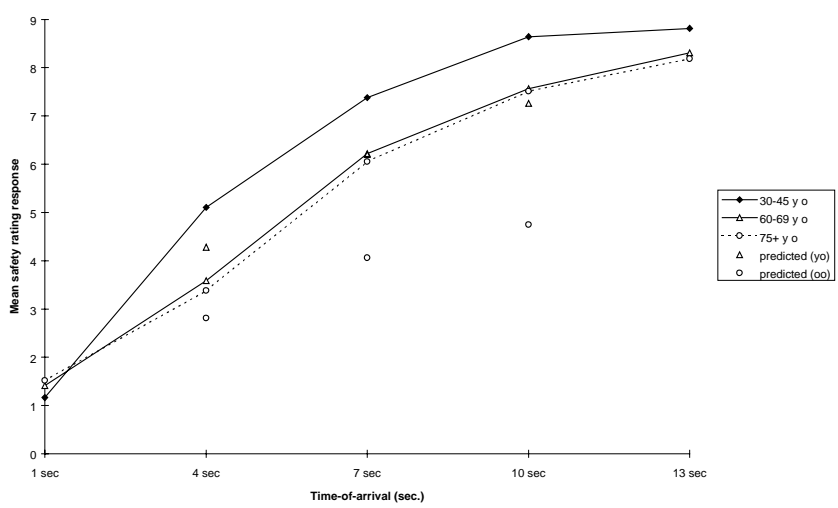


Figure 4: Mean safety rating responses - time-of-arrival by age group

DISCUSSION - The results of the first experiment demonstrated that, in general, the decision-making process of older adults was different from that of younger adults when assessing safe gaps in the traffic in which to cross, and that these differences were apparent, even when these data were adjusted for mobility effects. A second important finding was that adults aged in their 60's behaved in the most conservative manner, demonstrating a lower proportion of yes decisions and lower safety ratings in critical time-of-arrival conditions compared to that predicted. Moreover, a substantial proportion of those aged over 75 years behaved in a more risky manner, demonstrating a higher proportion of yes decisions and higher safety ratings in these conditions compared to that predicted. In addition, a substantial proportion of this group accepted large unsafe margins, allowing insufficient time to cross the road safely. This was most pronounced for the slower walkers.

Differences in safety rating responses also suggested that younger and older adults differed in their perception of risk. The

younger group perceived the same gaps in the traffic as more safe than their older counterparts. While this is not surprising, considering faster walking speeds demonstrated by the younger group, the observed responses compared with the predicted responses for the oldest group suggested that a greater proportion of this group perceived risk as lower than expected.

Some research suggests that the elderly behave more carefully and conservatively than younger adults [Safety for Seniors Working Group, 1989; Harrell, 1990], while others contend that some older adults may not be aware of the impact of ageing on the ability to perform tasks and the extent of these declines [Sabey, 1988; Matthews, 1986], adding that the reduced information processing capacity of the elderly makes them less efficient at monitoring their own performance, less aware of their mistakes, and also less able to remember making mistakes [Holland & Rabbitt, 1992]. Others, too, have found that the elderly express the least fear about crossing roads, concluding that they may cross roads in a risky fashion because they are over-confident and fail to recognise the extent of the dangers around them [Jonah & Engel, 1983; Mathey, 1983]. The findings from this study suggest that adults in their 60's are aware of their limitations and compensate for their vulnerability, demonstrated by the over-conservative nature of their responses. In contrast, however, it is suggested that a proportion of the oldest adults experience difficulty in recognising traffic hazards around them and cross in potentially dangerous situations. The results may also suggest that losses occur in the compensatory senses in the oldest old, and, as a result, the potential for risk increases and adoption of compensatory behaviours becomes more difficult [Sabey, 1988; Yanik & Monforton, 1991].

Another explanation may lie in a difficulty in selecting appropriate or safe gaps in the traffic to compensate for their slower walking speeds. Lee, Young and McLaughlin (1984) claimed that perceiving the affordance of a gap entails combining information about the environment with information about one's own walking speed. With diminished perceptual, cognitive and motor abilities, however, some older adults may experience difficulty in accommodating their judgements of safe gaps in the traffic to slowed walking speeds.

A third explanation for age differences in crossing decisions may be that some older adults experience difficulty calculating time-of-arrival in order to make safe road crossing decisions. A number of previous studies have reported age-related errors in perceptual judgements of distance and velocity [Scialfa et al., 1991; Carthy et

al., 1995]. While the present results do not provide direct estimates of vehicle distance and speed, it appears that older adults may inaccurately under-or over-estimate distance and/or speed which may result in potentially dangerous decision errors (under-estimation of safe gaps) based on inaccurate perceptual judgements of distance and velocity. The present study also pointed to a reduced use of speed cues by the older groups and that a two-stage decision process is involved in judging safe gaps, where distance information is first sought, then vehicle speed information is then processed to modify the initial decision, however, it was difficult to separate the effects of each variable.

EXPERIMENT TWO

The second study was conducted to explore further the degree to which distance and speed information are used and whether age differences exist in the ability to utilise both sources of information quickly and instantaneously to arrive at a safe crossing decision. Triggs, Fildes and Koca (1994) demonstrated age differences in attention-sharing strategies, suggesting a difficulty in processing two sources of information simultaneously. Vehicle distance and velocity were separated experimentally by manipulating inspection time of the traffic scenes. It was assumed that a short inspection time of 1 second would provide distance cues but little or no velocity information (particularly for the older adults). In contrast, a longer inspection time of 5 seconds would provide ample time for participants to integrate both distance and velocity cues to calculate time-of-arrival. It was hypothesised that vehicle speed and inspection time would have no effect on the decisions of younger adults because they should be able to instantaneously take distance and vehicle speed information into account in the estimation of time-of-arrival. Conversely, it was expected that these variables should affect crossing decisions for the older adults, pointing to a difficulty in sequentially integrating distance and velocity information to arrive at an accurate time-of-arrival estimation.

METHOD

Participants - Forty five participants took part in this experiment consisting of 15 young adults aged between 30 and 45 years, 15 young-old adults age between 60 and 69 years and 15 old-old participants aged 75 years and over. All participants had taken part in the first experiment and were familiar with the task.

Procedure - The same apparatus as used in the first experiment was utilised in this study (see previous section for a full description

of the experimental setup). Video tapes of 24 traffic sequences in which three independent variables (time-of-arrival, vehicle speed and inspection time) were manipulated. There were three levels of time-of-arrival (4, 7, and 10 seconds), two levels of vehicle speed (40 and 80kmn/h) and two levels of inspection time (1 and 5 seconds). Presentation of traffic sequences was in random order, participants viewed each scene twice (a total of 48 traffic scenes were viewed), and they were instructed to make the same yes/no and safety rating responses as in the previous experiment.

RESULTS

Yes/no Responses - As in the first experiment, hierarchical modelling of the data was employed to hold the effects of mobility constant while examining the relationship of other independent variables including age, time-of-arrival, vehicle speed, gap distance and inspection time. Age, ($\chi^2_{(2)}=51.17$, $p<0.001$), time-of-arrival ($\chi^2_{(2)}=242.65$, $p<0.001$), vehicle speed ($\chi^2_{(1)}=97.47$, $p<0.001$) and gap distance ($\chi^2_{(5)}=269.8$, $p<0.001$) were all found to be significant predictors of crossing decisions. In addition, significant interactions of vehicle speed by inspection time ($\chi^2_{(1)}=6.25$, $p=0.01$) and of distance gap by inspection time ($\chi^2_{(5)}=10.67$, $p=0.05$) were revealed.

The proportion of yes responses by vehicle speed and inspection time for all groups is shown in Figure 5.

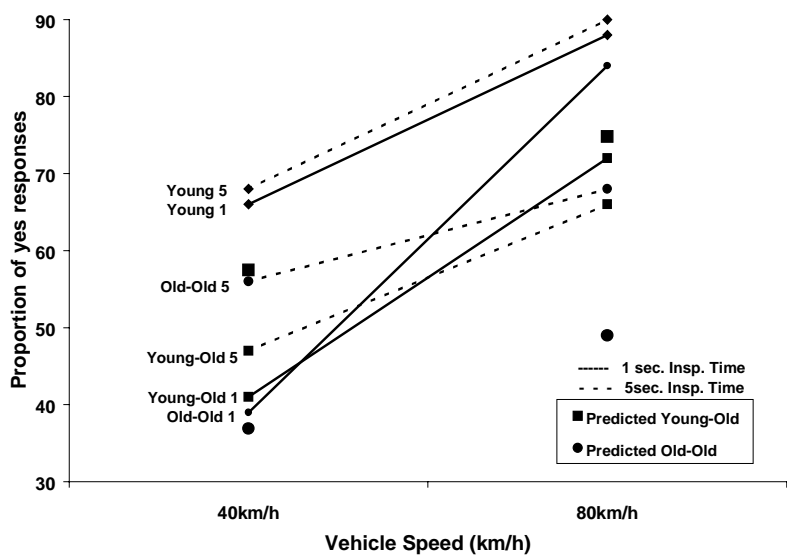


Figure 5: Proportion of yes responses - vehicle speed by age group and inspection time

Participants in the youngest group were more likely to indicate they would have crossed in both high and low vehicle speed conditions than those in the older groups. Inspection time did not affect the proportion of yes responses for the youngest group, however, it appeared to have affected the responses of the older groups, particularly those aged over 75 years. Participants in the oldest group were more likely to indicate they would have crossed with lower speeds in the short inspection time than in the long inspection time, however, were less likely to indicate they would have crossed with higher speeds in the short inspection time in contrast to the longer inspection time.

A theoretical proportion of yes responses was calculated for the older groups based on proportional walking speed of the youngest group. These are also shown in Figure 5. The young-old group made fewer yes responses than predicted suggesting conservative crossing decisions in both the low and high vehicle speed and long and short inspection time conditions. In contrast, a comparison between the observed and predicted responses of the oldest group revealed that a greater proportion of the oldest group indicated that they would have crossed than expected in all vehicle speed and inspection time conditions, but particularly so when vehicle speed was high and inspection time was short.

Safety Rating Responses - Safety rating responses were analysed employing a three-way repeated measures ANOVA which revealed significant main effects of group ($f_{(1,28)}=9.71$, $p<0.01$), vehicle speed ($f_{(1,28)}=179.69$, $p<0.001$), time-of-arrival ($f_{(2,56)}=407.34$, $p<0.001$) and inspection time ($f_{(1,28)}=11.83$, $p<0.01$). The ANOVA also revealed a significant interaction of time-of-arrival by inspection time ($f_{(2,56)}=4.17$, $p<0.05$).

Figure 6 shows time-of-arrival by age group and inspection time. In general, safety rating responses increased as time-of-arrival increased. The youngest group consistently rated the safety of crossing higher than the older groups, indicating that they perceived risk as lower in all time-of-arrival conditions than their older counterparts. Moreover, inspection time did not appear to greatly effect the ratings for either the youngest group or the oldest group. However, in the long time-of-arrival and long inspection time condition, the young-old group made low rating responses compared with a short inspection time.

In comparison with the predicted safety rating responses, the young-old group, in general made similar responses to that expected, except in the long time-of-arrival/long inspection time condition. In

this condition, their perceived risk was higher than expected. Conversely, the oldest group consistently made higher safety rating responses than that predicted in all time-of-arrival and inspection time conditions, suggesting that their perceived risk was lower than expected.

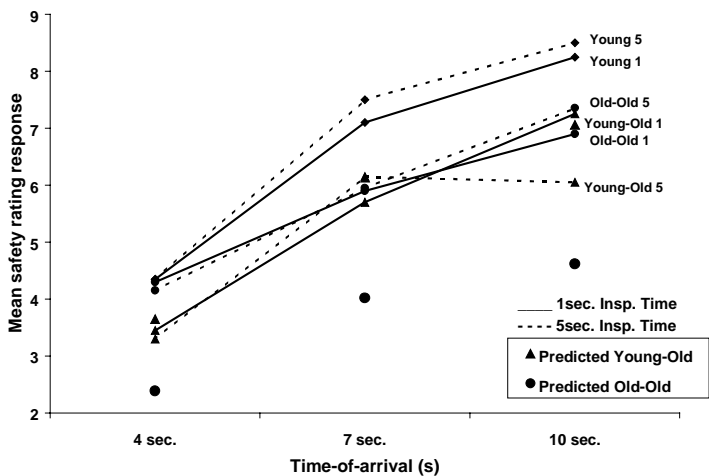


Figure 6: Mean safety rating responses – time-of-arrival by age group and inspection time.

Figure 7 shows vehicle speed by age group and inspection time. All groups perceived conditions of low vehicle speed as less safe than conditions of high vehicle speed when inspecting for short and long times. It should be noted that in similar time-of-arrival conditions, vehicles travelling at higher speeds appeared further away than vehicles travelling at lower speeds which may, to some degree, induced this finding.

The responses made by the youngest group were higher than those of both of the older groups and formed an almost linear relationship suggesting that inspection time did not effect rating responses for this age group. This was also the case for the young-old group, albeit at lower ratings. In contrast though, the responses for the oldest group formed a non-linear relationship between inspection times with long inspection times producing quite different rating responses to those in short inspection time conditions in this group. The oldest group perceived a short inspection time and low speed as less safe than other conditions, while a short inspection time and high vehicle speed was perceived as the most safe.

In comparison with the predicted safety rating responses the young-old group made similar responses in all conditions (high/low speeds and long/short inspection times). The oldest group, however,

consistently made higher safety rating responses than predicted. This was particularly so for the high speed/short inspection time condition.

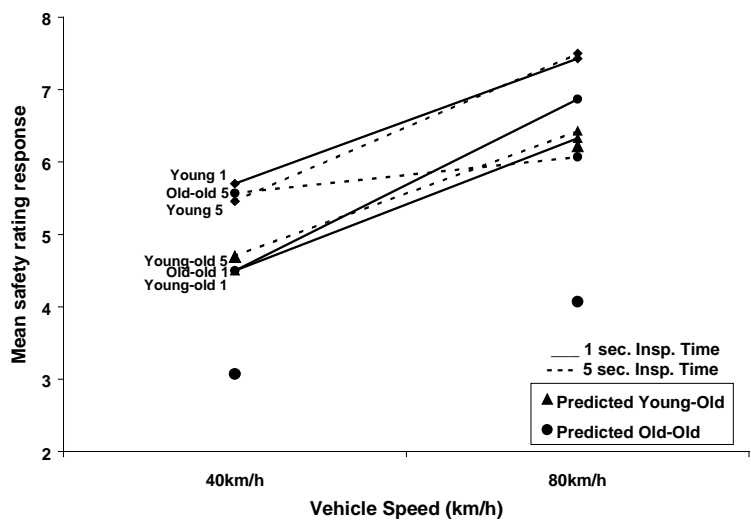


Figure 7: Mean safety rating responses – vehicle speed by age group and inspection time.

DISCUSSION - The second experiment was conducted to examine the contribution of distance and vehicle speed cues in the estimation of time-of-arrival when deciding on safe gaps in which to cross the road. The findings suggested that younger and older adults differed in their use of these cues. More specifically, the results clearly pointed to a two-stage model of decision-making (or a simultaneous/sequential information processing model) in which distance information is attended to first, then information on vehicle speed is integrated with distance information to arrive at an estimate of time-of-arrival. It appears that younger adults are able to efficiently and instantaneously integrate both sources of information to arrive at appropriate judgements of safe gaps in the traffic quickly. By contrast, older adults appeared to experience difficulty in quickly and instantaneously combining these sources of information and consequently made inaccurate perceptual judgements of time-of-arrival. This meant that in some situations (particularly when vehicles were travelling fast) older adults failed to modify their initial distance-based calculation of time-of-arrival to account for vehicle speed. The finding that low speeds were judged to be less safe than fast speeds suggests that adults of all ages place more emphasis on threatening ‘nearer’ objects and supports the notion that distance is paramount for judging safe road crossing.

Others have also suggested that older adults lack appropriate consideration of the speed of approaching vehicles [Elliott, Elliott & Lysaght, 1995; Carthy et al., 1995]. Carthy and his colleagues (1995) obtained measures of arrival time estimates at various speeds when vehicles disappeared from view at a number of distances from an endpoint. From these results they computed variables by least squares regression to represent the indices of distance and speed and found that judgements tended to be dominated by the distance variable, with a low facility to utilise speed cues in arrival time estimates, particularly for those aged over 70 years compared with those in their 50's and 60's. While their method did not allow for precise measures of perceived relative speed, only measuring a respondent's ability to compensate for speed in terms of estimating a delay in arrival time, they suggested that older adults were poor at integrating speed information with distance cues.

The contention that older adults, compared with younger adults, are less able to integrate distance and speed cues to estimate time-of-arrival is supported by previous research. While Scialfa et al (1991) only recorded verbal estimates of distance and velocity which may or may not reflect functional perceptual estimates used in real traffic decisions, they demonstrated that, relative to younger adults, older adults tended to overestimate time-of-arrival at lower speeds and underestimate time-of-arrival at higher speeds, again, suggesting a problem in modification of a distance-based decision with speed information. They concluded that older drivers and pedestrians might believe they had more time to manoeuvre themselves than was actually the case, resulting in potentially dangerous decision errors based on inaccurate perceptual judgements of velocity. Cavallo and Laurent (1988) also found greater inaccuracies of estimates at high vehicle speeds and suggested that this may be due not only to interactions between factors related to speed, but also to impoverished visual conditions created by reduced binocular vision and reduced effective visual field in the periphery. While these visual capacities were not examined in the context of age in this research, considering the age-related limitations in dynamic visual acuity [Shinar & Scheiber, 1991], contrast sensitivity [Kausler, 1991], visual search [Madden, 1986] and reduced effective visual field [Ball & Owsley, 1991] it is highly possible that older adults would experience difficulties correctly estimating the time it will take an approaching vehicle to reach the point at which they wish to cross the road, particularly in a complex environment with high traffic volumes and high speed.

Crossing the road is a complex task requiring the integration of information from multiple sources and it may be that when a number

sources of information must be attended to concurrently, older adults may perform less well than their younger counterparts because mental operations take longer to perform and their behavioural slowing is amplified as the task involves a greater number of operations [Fisk & Rogers, 1991]. From a limited resources approach, it may be that older adults have fewer resources available than younger adults to process both distance and speed information simultaneously and the increased need for resources to attend to one source of information must be met at the expense of their availability to a second or third source of information [McDowd & Craik, 1988].

It may also be that limitations in the integrated uptake and processing of information from multiple sources, and limitations in combining related actions result in deteriorations in attention switching and ability to prioritise the appropriateness of subtasks can account for age differences [Korteling, 1992]. Wickens (1987) discussed the factors that allow time-sharing to be carried out with efficiency within a limited resources framework. He suggested that the ability to process information in parallel enables the information-processing system to handle and transform information from multiple sources simultaneously. On the other hand, a less efficient system (one in which fewer resources are available) would mean that instead of time-sharing, a time-swapping strategy might be employed in which information might be processed in a more serial manner.

A reduced ability to attend to two or more sources of information, that is, vehicle distance and speed, and integrate the information in a short space of time would imply that, in comparison with a younger pedestrians, an older pedestrian may experience difficulty in estimating the time it will take an approaching vehicle to arrive at the crossing point and in making a safe gap selection in which to cross. When attempting to cross the road in front of oncoming traffic, some older adults may experience difficulty in quickly combining information of vehicle speed with distance information, resulting in a failure to modify an initial distance-based decision in adequate time with consequent inaccurate perceptual judgements of arrival time of oncoming vehicles.

CONCLUSIONS

This study has provided a detailed account of decision making processes involved in crossing the road and has highlighted differences between younger and older adults' decision-making processes regarding gaps in the traffic in which to cross roads safely which may, in part, contribute to the increased crash involvement rate of older pedestrians. The findings point to adoption of a

conservative strategy by adults in their 60's, possibly as a result of being more aware of age-related limitations. In contrast, it appears that some older adults may experience difficulty in judging safe gaps in which to cross as a result of a reduced awareness of limitations, a reduced ability to compensate for limitations and as a result of perceptual misjudgments in estimating appropriate time-of-arrival of approaching vehicles. A two-phase model of road crossing decisions was proposed to account for age differences in time-of-arrival estimations. It was suggested that younger adults are able to process and integrate distance and speed information in parallel to arrive at appropriate crossing decisions. An age-related reduced ability to integrate distance and speed information in parallel, however, may result in erroneous distance-based decisions errors in road crossing decisions by some older adults when faced with making quick decisions in fast moving traffic.

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